Spectral characterization of XUV sources based on plasmas induced by laser and capillary discharge

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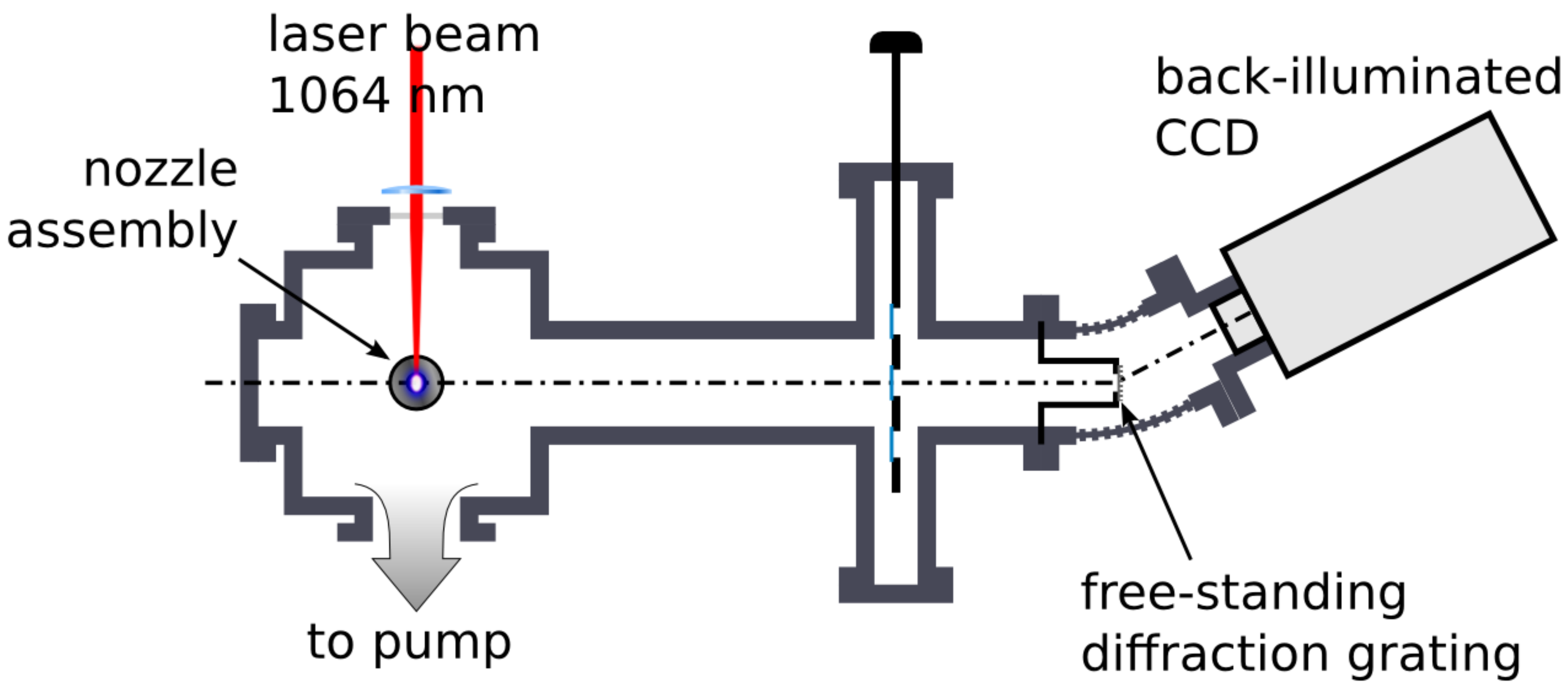
Introduction

Discharge produced plasma (DPP) and laser-produced plasma (LPP) are widely used technologies for generation of extreme ultraviolet (XUV) radiation. They provide interesting alternatives to synchrotron since they can be used for less demanding applications with several advantages. We have build a free-standing grating spectrometer for a routine diagnostics of the radiation generated by our two XUVlaboratory sources – a laser-produced plasma system (Laser-Laboratorium Goöttingen, e.V., Germany) and a pinching capillary discharge plasma system developed at the Faculty of Nuclear Sciences and Physical Engineering. Here we present a comparison of performance of the two sources in the XUV "water window" region. The spectral line at 2.88 nm emitted by nitrogen plasma was of particular interest because it can be used for quasi-monochromatic imaging.

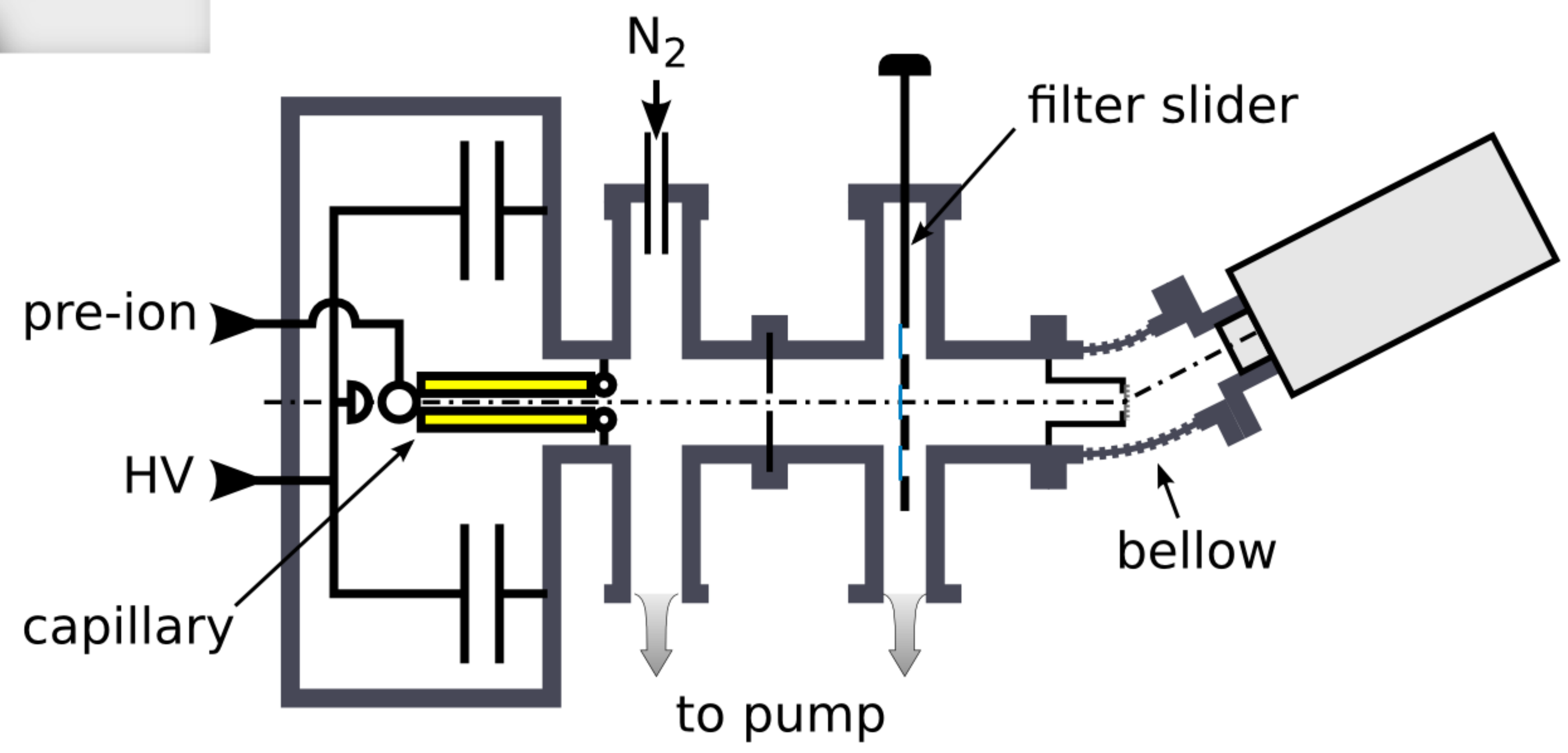
Laser-produced plasma source

The source is based on a Q-switched Nd:YAG laser (SpitLight 600, Innolas, GmbH) delivering 750 mJ, 7 ns pulses onto a gas-puff target. The target is created by pulsed injection of gaseous nitrogen into vacuum by a high-pressure piezoelectric valve through a conical tungsten nozzle. The duration of the XUV pulses is 4.5 ns. The maximal repetition rate of the source is 2 Hz.



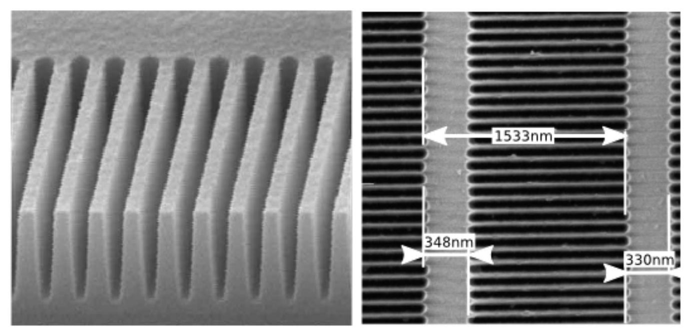
Capillary discharge plasma source

Alumina capillary of 3.2 mm diameter and 20 cm length is filled with nitrogen of initial pressure 40 - 80 Pa. The 300 ns current pulse with amplitude 13.5 kA is created by discharging 25 nF capacitors initially charged to 70-80 kV. The source can be operated at up to 10 Hz.



Spectrograph

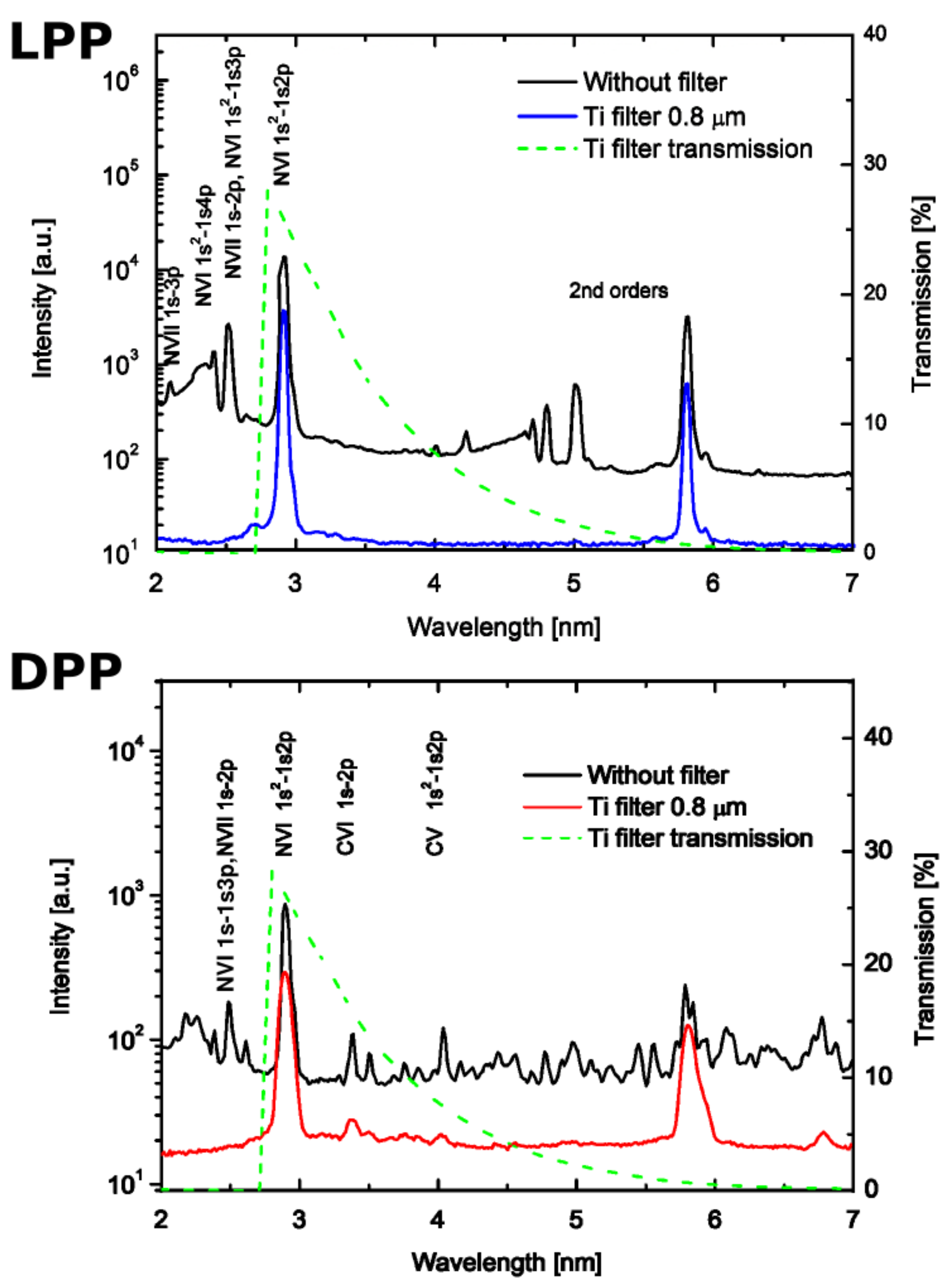
The spectrometer is using a free-standing silicon nitride grating with 100 nm period and ~0.5 open ratio. Back-thinned back-illuminated CCD camera X–Vision M25 (Rigaku) was used. The source-to-grating distance was 98 cm and grating-to-CCD 17 cm. A slit of 30 μm width was placed in front of the grating. The spectral resolution of the spectrograph was 0.01 nm.



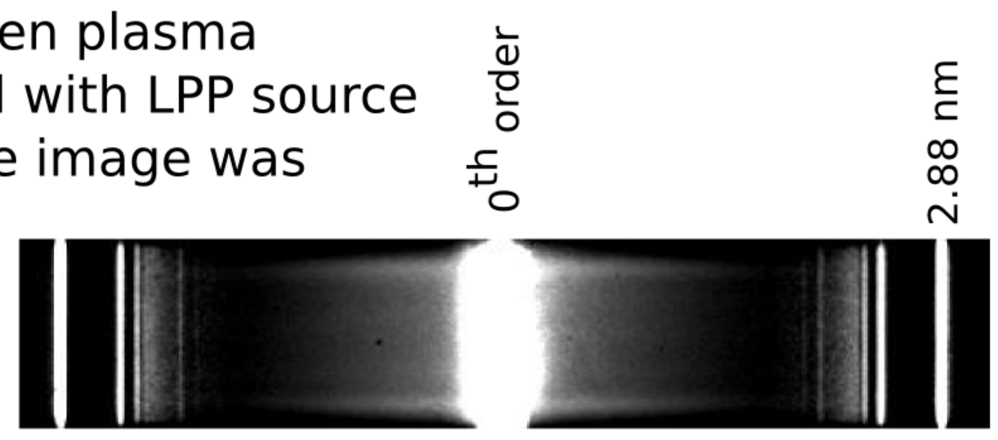
SEM image of the Si_3N_4 grating

Emission spectra

Comparison of emission spectra recorded using LPP (top) and DPP (bottom) source, respectively. Both sources produce radiation with good monochromaticity in combination with titanium filter (transmission shown in green). The main emission peak at 2.88 nm originates in the 1s2p → $1s^2$ transition of He-like nitrogen ions. Additional weak lines at 3.37 and 3.50 nm can be recognized in the spectrum of the DPP source. These lines correspond to hydrogen-like and helium-like carbon ion transitions.



An image of nitrogen plasma spectrum recorded with LPP source without a filter. The image was acumulated over 120 pulses



Pulse energy

The pulse energy was estimated for both sources from the intensity of the 1st diffraction order of the 2.88 nm emission line and from the known detection efficiency. The pulse energy produced by the DPP source at 2.88 nm was found to be approx. one order higher compared to LPP.

source	energy per pulse
LPP	2.8×10^{11} photons/srad
DPP	2.3×10^{12} photons/srad

References

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